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NISHIMURA SHOJI**(54) STEEL FOR COLD WORKING EXCELLENT IN INDUCTION HARDENABILITY, PARTS OF MACHINE STRUCTURE AND ITS PRODUCTION****(57)Abstract:**

PROBLEM TO BE SOLVED: To produce steel excellent in cold workability after spheroidizing annealing and induction hardenability having graded grains without grain coarsening even if induction hardening is executed under the conditions of high temp. and long time, to provide parts for machine structure using it as a base material and to provide a method for producing the same.

SOLUTION: The parts for machine structure contain (1) 0.40 to 0.6% C, >1.0 to 0.30% Si, 0.10 to 0.60% Mn, 0.0005 to 0.005% B, 0.005 to 0.05% Nb, 0.005 to 0.05% Ti, >0.050 to 0.10% Al, and the balance Fe with impurities, and, in the impurities, ≤0.015% P, ≤0.015% S, ≤0.10% Cu, ≤0.10% Ni, ≤0.15% Cr, ≤0.10% Mo, ≤0.005% N and ≤0.005% O are controlled. (2) The base material has the chemical compsn. of (1) and provided with a quench-hardening layer of spheroidized carbides and graded grains of ≥5 JIS grain size number. (3) The steel is heated to ≥1200° C, and thereafter subjected to hot working and then subjected to spheroidizing annealing and cold working to be formed into a prescribed shape, and, after that, induction hardening is executed finally to produce the parts.

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CLAIMS

[Claim(s)]

[Claim 1] By weight %, C:0.40 – 0.60% and Si:0.10% are exceeded. 0.30% or less, Mn: 0.10–0.60%, B:0.0005 – 0.005%, Nb:0.005–0.05%, Exceed Ti:0.005–0.05% and aluminum:0.050% and 0.10% or less is contained. The remainder consists of Fe and an unescapable impurity. P in an impurity 0.015% or less, For S, 0.005% or less and O (oxygen) are the steel for cold working which was excellent in the induction hardening nature 0.10% or less and whose N of 0.15% or less and Mo 0.10% or less and Cr are [Cu] 0.005% or less for 0.10% or less and nickel 0.015% or less.

[Claim 2] The carbide with which a base material has chemical composition according to claim 1, and spheroidized, and the machine structural steel worker components with which an austenite grain size is equipped with the hardening hardening layer of a with a JIS grain-size numbers of five or more particle size regulation.

[Claim 3] The manufacture approach of the machine structural steel worker components which hot working is carried out after heating at 1200 degrees C or more, and are subsequently characterized by carrying out cold working, fabricating the steel materials which have the chemical composition according to claim 1 by which spheroidizing was carried out in a predetermined configuration, and carrying out induction hardening after that.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to a machine structural steel worker component and its manufacture approach at the steel list for cold working excellent in induction hardening nature. In more detail, the deformation resistance at the time of cold working is small, and is excellent in induction hardening nature, and, moreover, for example, heating unit skin temperature is related with the machine structural steel worker component with which the holding time used as the base material steel for cold working which do not coarse-grain-ize even if it carries out induction hardening on condition that [former /, such as 10 seconds,] an elevated temperature and long duration, that is, is a ready fine grain, and its steel at 1150 degrees C, and its manufacture approach.

[0002]

[Description of the Prior Art] Conventionally, after machine structural steel worker components, the constant-velocity joint which are the circumference components of a guide peg of an automobile especially cut the machine structural steel worker medium-carbon-steel steel materials (S45C, S48C, etc.) of JIS by which hot forging was carried out and they carried out fabrication to the predetermined configuration, induction hardening of it was carried out, and it was further manufactured by annealing if needed.

[0003] However, since dimensional accuracy was inferior in the case of hot forging, it needed to heavy machine, in order to fabricate in a predetermined configuration, and the cost of cutting increased, and it was not able to avoid that the yield became low further. Then, dimensional accuracy is high, therefore cold forging which can reduce the amount of cutting has come to be adopted in recent years.

[0004] When performing the above-mentioned cold forging, in order to lower deformation resistance, spheroidizing is beforehand given to a work material. However, since deformation resistance was high even if it performed spheroidizing annealing when the above mentioned machine structural steel worker medium-carbon-steel steel materials of JIS were used, also when strong processing was performed at the time of cold forging and a crack arose on the components by which the tool life fell, and cold forging was carried out since deformability was low, it was.

[0005] Furthermore, in recent years, induction hardening has been performed more often on condition that an elevated temperature and long duration compared with the former for the purpose of high-intensity-izing of machine structural steel worker components. However, if induction hardening is carried out on such conditions, in the case of the above mentioned machine structural steel worker medium-carbon-steel steel materials of JIS, it will coarse-grain-ize extremely.

[0006] The technique of making formability in cold forging improving is proposed by JP,1-38847,B, JP,2-47536,B, JP,5-59486,A, JP,9-268344,A, JP,9-272946,A, JP,9-287054,A, JP,9-287055,A, JP,2-145744,A, etc., securing induction hardening nature to such a problem.

[0007] However, since the steel proposed by JP,1-38847,B had few contents of aluminum, it had the case where the hardening disposition top effectiveness of B was difficult to get.

[0008] Since there were few contents of aluminum, the steel proposed by JP,2-47536,B and JP,5-59486,A may have the hardening disposition top effectiveness of B difficult to get, and since it moreover did not contain Nb, it had the case where big and rough-ization of crystal grain was produced. Furthermore, since the content of Si was low, there was a case where the detachability of the scale produced with heating before hot working was inferior.

[0009] Since there were few contents of aluminum, the steel indicated by JP,9-268344,A and JP,9-272946,A may have the hardening disposition top effectiveness of B difficult to get, and since it moreover did not contain Nb, it had the case where big and rough-ization of crystal grain was produced.

[0010] Since the steel proposed by JP,9-287054,A had the high content of Si, it was what cannot avoid degradation of cold-working nature easily.

[0011] Since the steel indicated by JP,9-287055,A had the high content of Mn, it was what cannot avoid degradation of cold-working nature easily.

[0012] As for the technique indicated by JP,2-145744,A, compound addition of Nb and Ti is not carried out. For this reason, when induction hardening of the steel proposed in this official report was carried out, there was a case where big and rough-ization of crystal grain was produced. If induction hardening is performed on condition that an elevated temperature and long duration compared with the former for the purpose of high-intensity-izing machine structural steel worker components especially, it will coarse-grain-ize extremely. Furthermore, since the steel proposed in the above-mentioned official report did not contain B as an essential element, it had the case where the desired induction hardening depth was not obtained. And in the case of the steel which does not contain B, since there were many contents of an alloy element compared with the steel containing B which has equivalent hardenability, the deformation resistance at the time of cold forging might become high, and formability in cold forging might be inferior. In addition, it was what cannot avoid easily that the scale generated by hot working or spheroidizing cannot fall easily due to the process of descaling, and carry out a long duration important point to descaling, or the process becomes complicated.

[0013]

[Problem(s) to be Solved by the Invention] This invention aims at offering the machine structural steel worker component which used as the base material the steel for cold working and steel of the low cost die which was made in view of the above-mentioned present condition, does not coarse-grain-ize even if the deformation resistance at the time of cold working which makes cold forging the start is small, and is excellent in induction hardening nature and it moreover carries out induction hardening on condition that an elevated

temperature and long duration conventionally, but presents a ready fine grain, and its manufacture approach. Specifically the deformation resistance at the time of cold working is low 10% or more, moreover, the limitation which the crack as deformability generates sets to the JIS machine structural carbon steel of equivalent C content, and the rate of a lump is 85% or more. The hardening depth set to 400 with Vickers hardness (Hv) when induction hardening is carried out t, t/r is 0.3 or more, using the average diameter of the induction hardening section as r, and at 1150 degrees C, even if heating unit skin temperature carries out induction hardening on conditions which the holding time calls 10 seconds It aims at the hard spots after induction hardening, i.e., the austenite grain size of a hardening hardening layer mentioned later, being five or more JIS grain-size numbers, and being a particle size regulation. In addition, the "hardening hardening layer" which is a hard spot after induction hardening points out the thing of the part which becomes 400 or more by Hv. A "particle size regulation" means consisting of a grain without or more 3 difference by the grain-size number.

[0014]

[Means for Solving the Problem] This invention makes a summary the manufacture approach of the machine structural steel worker components shown in the machine structural steel worker components shown in the steel for cold working excellent in the induction hardening nature shown in following (1), and a list (2), and (3).

[0015] By weight %, C:0.40 - 0.60% and Si:0.10% are exceeded. (1) 0.30% or less, Mn: 0.10-0.60%, B:0.0005 - 0.005%, Nb:0.005-0.05%, Exceed Ti:0.005-0.05% and aluminum:0.050% and 0.10% or less is contained. The remainder consists of Fe and an unescapable impurity. P in an impurity 0.015% or less, For S, 0.005% or less and O are the steel for cold working which was excellent in the induction hardening nature 0.10% or less and whose N of 0.15% or less and Mo 0.10% or less and Cr are [Cu] 0.005% or less for 0.10% or less and nickel 0.015% or less.

[0016] (2) The carbide with which a base material has the chemical composition of a publication in the above (1), and spheroidized, and the machine structural steel worker components with which an austenite grain size is equipped with the hardening hardening layer of a with a JIS grain-size numbers of five or more particle size regulation.

[0017] (3) The manufacture approach of the machine structural steel worker components which hot working is carried out after heating at 1200 or more degrees C, and are subsequently characterized by carrying out cold working of the steel materials which have the chemical composition of a publication in the above (1) by which spheroidizing was carried out, fabricating them in a predetermined configuration, and carrying out induction hardening after that.

[0018] In addition, as it was already described as the "hardening hardening layer" as used in the field of above (2), the thing of the part set to 400 or more Hv(s) with hardening is pointed out, and a "particle size regulation" says consisting of a grain without or more 3 difference by the grain-size number.

[0019] this invention persons did plastic working by cold working, such as cold forging, after spheroidizing, and performed investigation and examination about the chemical composition of the steel used as the base material of the machine structural steel worker components subsequently conventionally manufactured by the induction hardening in elevated-temperature long duration. Consequently, the following knowledge was acquired.

[0020] ** Since it is big and rough, as for the niobium titanium carbon nitride [NbTi (CN)] which deposits in case the steel which carried out compound addition of Nb and Ti solidifies, there is no effectiveness in big and rough-ized prevention of the austenite grain at the time of induction hardening. However, if above [NbTi (CN)] is made detailed, since the so-called "pinning operation" will be demonstrated, big and rough-ization of an austenite grain can be prevented.

[0021] ** What is necessary is to make high whenever [stoving temperature / in the case of hot working], to make a base once dissolve, and just to make it re-deposit at the time of following processing and cooling, in order to make [NbTi (CN)] detailed.

[0022] ** Big and rough-ized prevention of the austenite grain by above detailed [NbTi (CN)] is demonstrated greatly [when especially Mn content of steel is low], at 1150 degrees C, even if heating unit skin temperature carries out induction hardening of it on condition that [former / which the holding time calls 10 seconds] an elevated temperature and long duration, it does not coarse-grain-ize it, but it serves as a ready fine grain.

[0023] ** While stopping Mn content low, even if [NbTi (CN)] is detailed, in the case of the steel which made Si, Nb, Ti, aluminum, and B of a proper amount contain, fully soften in the usual spheroidizing. Therefore, it compares with the JIS machine structural carbon steel of equivalent C content, the deformation resistance at the time of cold working is low, and, moreover, deformability is large enough.

[0024] ** The steel which adjusted the content of Mn, Nb, Ti, aluminum, and B, and adjusted the content of N as an impurity element low has good induction hardening nature.

[0025] ** Heating unit skin temperature can fill easily [above mentioned t/r / 0.3 or more] with 1150 degrees C the steel which adjusted the content of C, Mn, Nb, Ti, aluminum, and B, and adjusted the content of N as an impurity element low, even if it carries out induction hardening on condition that [former / which the holding time calls 10 seconds] an elevated temperature and a long time.

[0026] This invention is completed based on the above-mentioned knowledge.

[0027]

[Embodiment of the Invention] Hereafter, each requirement for this invention is explained in detail. In addition, "% of the content" of a chemical entity means "% of the weight."

[0028] (A) C:0.40 - 0.60% of chemical composition C of base material steel is the element which affects induction hardening nature, and it is an element effective in securing the hardness and the depth of a hardening hardening layer, and giving a desired mechanical property to machine structural steel worker components. However, the content is deficient in the addition effectiveness at less than 0.40%. On the other hand, when it is made to contain exceeding 0.60%, cold-working nature may deteriorate, without fully softening, even if it carries out spheroidizing, or degradation of toughness and generating of a quench crack may be caused. Therefore, the content of C was made into 0.40 - 0.60%.

[0029] Si: 0.10% is exceeded and 0.30% or less Si has the effectiveness which raises stabilization and reinforcement of deoxidation of steel. Furthermore, since the steel which added Si generates the fire light (Fe₂SiO₄) which is a low-melt point point oxide during heating for hot working, descaling nature will become very good if it heats more than the melting point (1173 degrees C). However, the content is deficient in the addition effectiveness at 0.10% or less. On the other hand, if a content is carried out exceeding 0.30%, the deformation resistance at the time of cold working will become large, and will cause the fall of cold-working nature. Therefore, it exceeded 0.10% and the content of Si was made into 0.30% or less. In addition, it is good to make Si contain exceeding 0.15% preferably.

[0030] Mn: 0.10 – 0.60%Mn is an effective element in order to secure reinforcement, while fixing S in steel and raising hot-working nature, and it needs making it contain 0.10% or more. On the other hand, if the content of Mn exceeds 0.60%, deformation resistance will become large and will cause degradation of cold-working nature. Therefore, the content of Mn was made into 0.10 – 0.60%. In addition, as for Mn content, considering as 0.10 – 0.40% is desirable.

[0031] B: 0.0005 – 0.005%B is an element effective in securing good induction hardening nature, without checking cold-working nature. However, the content is deficient in the addition effectiveness at less than 0.0005%. On the other hand, if it is made to contain exceeding 0.005%, about [that the effectiveness is saturated] and grain boundary embrittlement may be caused. Therefore, the content of B was made into 0.0005 – 0.005%.

[0032] Nb: Although 0.005–0.05%Nb combines with Ti and forms [NbTi (CN)], if this [NbTi (CN)] is deposited minutely, even when induction hardening is carried out on condition that [before] an elevated temperature and a long time, it can prevent coarse-grain-ization. However, the effectiveness of a request of the content at less than 0.005% is not acquired. On the other hand, when it exceeds 0.05%, making deformation resistance increase may not be avoided, and big and rough non-dissolved carbon nitride may remain, and degradation of cold-working nature may be caused. Therefore, the content of Nb was made into 0.005 – 0.05%. In addition, considering as 0.03% is desirable, and if the upper limit of Nb content is made into 0.02%, it is much more desirable.

[0033] Ti: Although 0.005 – 0.05%Ti combines with Nb and forms [NbTi (CN)], if this [NbTi (CN)] is deposited minutely, even when induction hardening is carried out on condition that [before] an elevated temperature and a long time, it can prevent coarse-grain-ization. However, the content is deficient in the addition effectiveness at less than 0.005%. On the other hand, when it exceeds 0.05%, making deformation resistance increase may not be avoided, and big and rough non-dissolved carbon nitride may remain, and degradation of cold-working nature may be caused. Therefore, the content of Ti was made into 0.005 – 0.05%. In addition, considering as 0.03% is desirable, and if the upper limit of Ti content is made into 0.015%, it is much more desirable.

[0034] aluminum: 0.050% is exceeded and aluminum has deacidification 0.10% or less. Furthermore, since a nitride is generated and N in steel is fixed, there is an operation which controls work hardening at the time of cold working. Moreover, it is effective also in securing the induction hardening disposition top effectiveness of B by immobilization in [N] steel. However, the content is deficient in the addition effectiveness at 0.050% or less. On the other hand, if it is made to contain exceeding 0.10%, the deformability of steel will fall at the time of cold working. Therefore, the content of aluminum was made into 0.10% or less exceeding 0.050%.

[0035] In this invention, P, S, Cu, nickel, Cr, Mo, N, and O as an impurity element are restricted as follows.

[0036] P: 0.015% or less P will reduce the deformability at the time of cold working. If the content of P exceeds 0.015% especially, the fall of the deformability at the time of cold working will become remarkable. Therefore, the content of P as an impurity element was made into 0.015% or less.

[0037] S: 0.015% or less S will also reduce the deformability at the time of cold working. If the content of S exceeds 0.015% especially, the fall of the deformability at the time of cold working will become remarkable. Therefore, the content of S as an impurity element was made into 0.015% or less.

[0038] Cu: Less than [0.10%] Cu will raise deformation resistance, and will degrade cold-working nature. If the content of Cu exceeds 0.10% especially, degradation of cold-working nature will become remarkable. Therefore, the content of Cu as an impurity element was made into 0.10% or less. In addition, as for Cu content, regulating to 0.05% or less is desirable.

[0039] nickel: 0.10% or less nickel will raise deformation resistance, and will degrade cold-working nature. Furthermore, descaling after spheroidizing is made difficult. If the content of nickel exceeds 0.10% especially, the fall of cold-working nature and the fall of descaling nature will become remarkable. Therefore, nickel content as an impurity element was made into 0.10% or less. In addition, as for nickel content, regulating to 0.05% or less is desirable.

[0040] Cr: Less than [0.15%] Cr will also raise deformation resistance, and will degrade cold-working nature. Furthermore, descaling after spheroidizing is made difficult. If the content of Cr exceeds 0.15% especially, the fall of cold-working nature and the fall of descaling nature will become remarkable. Therefore, Cr content as an impurity element was made into 0.15% or less. In addition, as for Cr content, regulating to 0.10% or less is desirable.

[0041] Mo: 0.10% or less Mo will raise deformation resistance, and will degrade cold-working nature. Furthermore, descaling after spheroidizing will be made difficult. If the content of Mo exceeds 0.10% especially, the fall of cold-working nature and the fall of descaling nature will become remarkable. Therefore, Mo content as an impurity element was made into 0.10% or less. In addition, as for Mo content, regulating to 0.05% or less is desirable.

[0042] N: 0.005% or less N will raise deformation resistance, and will degrade cold-working nature. Since it is easily connected with B and BN is formed, it becomes impossible furthermore, to secure the induction hardening disposition top effectiveness of B. If the content of N exceeds 0.005% especially, while the fall of cold-working nature becomes remarkable, the induction hardening disposition top effectiveness of B will become difficult to get. Therefore, N content as an impurity element was made into 0.005% or less. In addition, regulating to 0.004% or less is desirable, and if N content is made into 0.003% or less, it is much more desirable.

[0043] O (oxygen): 0.005% or less O will form an oxide, and will reduce the deformability at the time of cold working. If the content of O exceeds 0.005% especially, the fall of the deformability at the time of cold working will become remarkable. Therefore, the content of O as an impurity element was made into 0.005% or less.

[0044] (B) [NbTi (CN)] with the steel big and rough all over the solidification structure which has the chemical composition of a publication in the above (A) which carried out compound addition of the hot working Nb and Ti exists. This big and rough [NbTi (CN)] serves as an origin of the processing crack in next cold working, and does not have effectiveness in big and rough-ized prevention of the austenite grain at the time of induction hardening, either.

[0045] However, since high temperature, then high [NbTi (CN)] 1200 degrees C or more once dissolve on a base, whenever [stoving temperature / in the case of hot working which makes hot rolling the start] is minutely re-deposited at the time of following processing and cooling and the so-called "pinning operation" can be demonstrated, big and rough-ized prevention of an austenite grain is attained. Therefore, whenever [stoving temperature / of hot working] was made into 1200 degrees C or more. In addition, although it is not necessary to specify especially the upper limit of whenever [this stoving temperature], in order to hold down the energy cost for heating, to stop scale loss further and to raise the yield, considering as 1350 degrees C is desirable.

[0046] (C) The steel which has the chemical composition of a publication is processed into the spheroidizing above (A) between the post heating heated by the above (B) on condition that the publication, and further, in order to lower the deformation resistance at the

time of cold working, spheroidizing is given. What is necessary is not to specify especially this spheroidizing and just to perform it by the usual approach.

[0047] (D) Cold working, such as cold forging, is performed to the steel materials which have the chemical composition of a publication in the above (A) by which spheroidizing was carried out after cold-working hot working, and they are fabricated by the machine structural steel worker components of a predetermined configuration. What is necessary is not to specify especially the approach of this cold working and just to perform it by the usual approach.

[0048] In addition, in order to enable it to secure the particle size regulation organization of a with a JIS grain-size numbers of five or more which the hard spot after the induction hardening of the machine structural steel worker components fabricated by the configuration predetermined by cold working (hardening hardening layer) stabilizes for which and mentions later austenite grain size Cold working is good to carry out so that the amount of processings in the part which the biggest processing joins in processed components may become 2.5 or less by the equivalent strain expressed with the following (a) type, and if it is performed so that it may become 2.0 or less by the equivalent strain, it is much more desirable.

[0049]

$\epsilon = (\epsilon_{12} + \epsilon_{22} + \epsilon_{32}) \times 2 / 3$ One half (a)

ϵ_1 [in / here / the (a) type], ϵ_2 , and ϵ_3 It is the logarithmic strain of a principal direction.

[0050] (E) Induction hardening is carried out, or annealing is given after induction hardening if needed, and the machine structural steel worker components which have a desired mechanical property are made to the steel materials which have the chemical composition of a publication in the induction hardening above (A), spheroidizing was carried out after hot working, and cold working was carried out after that, and were fabricated by the predetermined configuration.

[0051] the austenite grain size in the hardening hardening layer of machine structural steel worker components is not less than 5 by the JIS grain-size number, or a particle size regulation — that is, the thing which heat treatment distortion produces in being a mixed grain size — in addition, toughness falls, dispersion in hardness (reinforcement) arises, and especially the fall of toughness when the reinforcement of machine structural steel worker components is high is remarkable. Therefore, it was prescribed that the hardening hardening layer of machine structural steel worker components was the particle size regulation of a with a JIS grain-size numbers of five or more austenite grain size. In addition, as for a JIS grain-size number, it is desirable that it is six or more. Since toughness improves the more the more a JIS grain-size number is larger as austenite crystal grain is small that is, it is not necessary to prepare an upper limit in a JIS grain-size number.

[0052] To the induction hardening in the conditions whose holding times are about several seconds at about 950 degrees C, the usual conditions, i.e., heating unit skin temperature, crystal grain does not make big and rough steel concerning this invention which has the chemical composition of a publication in the above (A), and a with a JIS grain-size numbers of five or more ready fine grain is obtained for an austenite grain size. Furthermore, even if heating unit skin temperature carries out induction hardening at 1150 degrees C on condition that [former / which the holding time calls 10 seconds] an elevated temperature and a long time, an austenite grain size is adjusted so that a with a JIS grain-size numbers of five or more ready fine grain may be obtained. For this reason, especially the approach of induction hardening is not specified.

[0053] In addition, the steel materials which carried out induction hardening after cold working twist, depending on the hardening depth which becomes 400 or more by Hv as the induction hardening depth, t/r twists reinforcement less than by 0.3, and reinforcement becomes small. Therefore, when the components by which induction hardening is carried out are large-sized that is, if r carries out induction hardening on condition that usual in being large, 0.3 or more may not be obtained by t/r. In such a case, it is necessary for heating unit skin temperature which was already described in order to secure 0.3 or more by t/r to carry out induction hardening at 1150 degrees C on condition that [former / which the holding time calls 10 seconds] an elevated temperature and long duration. Even if the steel concerning this invention which has the chemical composition of a publication in the above (A) is such a case, crystal grain does not make it big and rough.

[0054] Hereafter, an example explains this invention.

[0055]

[Example] The steel which has the chemical composition shown in Table 1 and Table 2 was ingoted using test kiln by the usual approach. Steel a-r in the steel of the example of this invention with which steel A-N in Table 1 has chemical composition within the limits of the content specified by this invention, and Table 1 is the steel of the example of a comparison from which either of the components separated from the range of the content specified by this invention. Steel p, Steel q, and Steel r are steel which is equivalent to S40C, S50C, and S58C of JIS, respectively among the steel of the example of a comparison.

[0056]

[Table 1]

表 1

区分	鋼	化学組成 (重量%)									残部: Fe および不純物					
		C	Si	Mn	P	S	Cu	Ni	Cr	Mo	B	Nb	Ti	Al	N	O
本発明例	A	0.41	0.23	0.16	0.011	0.012	0.01	0.02	0.09	0.02	0.0020	0.017	0.015	0.068	0.0038	0.0018
	B	0.40	0.26	0.28	0.009	0.009	0.01	0.02	0.15	0.01	0.0021	0.025	0.032	0.071	0.0045	0.0013
	C	0.57	0.11	0.32	0.015	0.011	0.01	0.01	0.12	0.01	0.0015	0.015	0.014	0.067	0.0039	0.0024
	D	0.42	0.12	0.54	0.011	0.012	0.02	0.02	0.07	0.01	0.0015	0.019	0.018	0.071	0.0036	0.0024
	E	0.41	0.22	0.38	0.013	0.012	0.01	0.03	0.08	0.01	0.0015	0.021	0.036	0.027	0.0040	0.0025
	F	0.57	0.08	0.24	0.010	0.008	0.03	0.02	0.12	0.01	0.0021	0.019	0.017	0.071	0.0038	0.0022
	G	0.50	0.35	0.22	0.008	0.009	0.01	0.01	0.07	0.01	0.0015	0.007	0.018	0.077	0.0047	0.0021
	H	0.48	0.05	0.31	0.011	0.013	0.01	0.01	0.15	0.03	0.0015	0.028	0.042	0.059	0.0048	0.0017
	I	0.54	0.30	0.46	0.012	0.012	0.01	0.04	0.12	0.02	0.0015	0.025	0.017	0.059	0.0041	0.0012
	J	0.44	0.35	0.25	0.010	0.011	0.01	0.01	0.07	0.02	0.0013	0.014	0.018	0.067	0.0035	0.0016
	K	0.53	0.24	0.21	0.008	0.010	0.01	0.02	0.08	0.02	0.0017	0.017	0.039	0.045	0.0047	0.0015
	L	0.58	0.13	0.20	0.011	0.010	0.01	0.01	0.07	0.01	0.0015	0.042	0.022	0.077	0.0038	0.0025
	M	0.41	0.06	0.10	0.013	0.011	0.01	0.03	0.08	0.02	0.0015	0.026	0.046	0.061	0.0035	0.0015
	N	0.49	0.33	0.38	0.010	0.012	0.01	0.05	0.11	0.05	0.0015	0.017	0.017	0.065	0.0034	0.0014

[0057]

[Table 2]

表 2

区分	鋼	化学組成 (重量%)									残部: Fe および不純物					
		C	Si	Mn	P	S	Cu	Ni	Cr	Mo	B	Nb	Ti	Al	N	O
比較例	a	*0.67	0.34	0.32	0.012	0.012	0.01	0.01	0.08	0.01	0.0012	0.024	0.025	0.051	0.0031	0.0017
	b	0.42	*0.52	0.29	0.011	0.011	0.01	0.03	0.09	0.02	0.0014	0.022	0.028	0.070	0.0022	0.0014
	c	0.42	0.36	*0.91	0.011	0.009	0.01	0.01	0.11	0.03	0.0017	0.020	0.035	0.044	0.0033	0.0015
	d	0.54	0.37	0.45	*0.022	0.010	0.01	0.02	0.14	0.01	0.0018	0.017	0.041	0.078	0.0038	0.0032
	e	0.44	0.21	0.18	0.012	*0.024	0.01	0.01	0.05	0.01	0.0011	0.025	0.017	0.080	0.0029	0.0027
	f	0.54	0.23	0.22	0.011	0.009	*0.14	0.10	0.06	0.01	0.0022	0.015	0.035	0.085	0.0044	0.0023
	g	0.53	0.21	0.34	0.011	0.010	0.01	*0.20	0.05	0.02	0.0020	0.009	0.038	0.057	0.0037	0.0015
	h	0.55	0.24	0.56	0.010	0.013	0.01	0.02	*0.28	0.01	0.0019	0.018	0.028	0.088	0.0043	0.0014
	i	0.41	0.26	0.21	0.011	0.011	0.01	0.01	0.09	*0.15	0.0014	0.024	0.006	0.065	0.0032	0.0035
	j	0.45	0.08	0.55	0.013	0.014	0.01	0.03	0.14	0.02	*	0.023	0.017	0.032	0.0045	0.0015
	k	0.54	0.05	0.17	0.010	0.012	0.02	0.04	0.12	0.02	0.0019	*0.001	0.037	0.059	0.0026	0.0017
	l	0.42	0.09	0.59	0.009	0.011	0.01	0.02	0.09	0.01	0.0022	0.022	*0.001	0.054	0.0038	0.0019
	m	0.58	0.29	0.54	0.010	0.010	0.01	0.02	0.12	0.02	0.0015	0.020	0.040	*0.120	0.0047	0.0032
	n	0.45	0.06	0.55	0.012	0.012	0.01	0.02	0.09	0.02	0.0023	0.017	0.032	0.089	*0.0075	0.0032
	o	0.52	0.34	0.17	0.011	0.010	0.01	0.02	0.12	0.01	0.0019	0.019	0.028	0.065	0.0037	*0.0062
	p	0.40	0.31	*0.76	*0.022	*0.018	0.01	0.02	0.15	0.01	*	0.001	*0.001	0.052	*0.0053	*0.0063
	q	0.50	0.28	*0.80	*0.020	*0.020	0.01	0.02	0.15	0.01	*	0.001	*0.001	0.056	*0.0063	*0.0056
	r	0.58	0.35	*0.74	*0.017	*0.016	0.01	0.02	0.13	0.01	*	0.001	*0.001	0.069	*0.0081	0.0042

*印は本発明で規定する条件から外れていることを示す。

[0058] Subsequently, after making such steel into slab by the usual approach, hot forging was heated and carried out to 1100 degrees C or 1250 degrees C, and it considered as the round bar with a diameter of 65mm. Then, according to C content, spheroidizing was performed by the usual approach.

[0059] From the R/2 section (R is the radius of the round bar) of the round bar whose diameter obtained as mentioned above is 65mm, the diameter cut down the test piece for cold working whose die length is 22.5mm by 15mm, and performed the constraint type **** lump trial between the colds (room temperature) by the usual approach by 500t high-speed press machine, the limitation which a crack generates set, and the rate of a lump was measured. In addition, it set, and to 85%, for every monograph affair, it set, the lump trial was performed and the rate of a lump evaluated 5 times of the minimum working ratio (setting rate of a lump) which a crack generates or more in three of five test pieces as a rate of a marginal **** lump. What sets and does not produce a three or more piece crack at 85% of rates of a lump ended the trial there.

[0060] furthermore, 60% which is below the rate of a marginal **** lump of all steel — it set and the deformation resistance in the case of the rate of a lump (the equivalent strain in the test piece core where the biggest processing is added is 1.5) was measured. In addition, as shown in drawing 1, deformation resistance was arranged with the content of C, the straight line for which it asked from the deformation resistance of the steel p equivalent to S40C, S50C, and S58C of JIS, Steel q, and Steel r was made into the deformation resistance of JIS steel for machine structural use, and it compared with the deformation resistance of the steel of the

example of this invention of steel A-N, and the steel of the example of a comparison of steel a-o.

[0061] Moreover, from the round bar with an above-mentioned diameter of 65mm, the diameter cut down the test piece whose die length is 50mm by 63mm, and the diameter performed between the colds front extruding (60% (it is 1.3 at the equivalent strain of the test piece side surface section which the biggest processing joins, i.e., the test piece outermost layer) of reduction of area) to 40mm by the usual approach. The test piece with a die length of 50mm was extracted from what carried out extruding to this diameter of 40mm between the colds, and induction hardening was performed to this. High-frequency heating carried out the average heating rate in 200 degrees C/second, and performed it on the following two conditions. That is, they are the high-frequency-heating conditions in the frequency of 20kHz for enlarging the frequency of 20kHz, the heating unit skin temperature of 950 degrees C, the general high-frequency-heating conditions for holding-time 2 seconds, and the hardening depth, and high-intensity-izing them, the heating unit skin temperature of 1150 degrees C, and the elevated temperature and long duration for holding-time 10 seconds. In addition, water was used for the cooling medium.

[0062] After performing induction hardening, hardening depth (that is, depth of hardening hardening layer) t set to 400 by surface hardness and Hv by the usual approach was measured. Subsequently, annealing for 30 minutes was performed at 150 degrees C using the electric furnace, and the hard spot after induction hardening, i.e., the austenite grain size of a hardening hardening layer, was measured by the usual approach.

[0063] The above-mentioned test result is collectively shown in Table 3 and 4. In addition, r in this example is the radius of a test piece with a diameter of 40mm, i.e., 20mm.

[0064]

[Table 3]

区分	試験番号	鋼	熱間鍛造における加熱温度(℃)	試験			高周波焼入れ				
				据込み抵抗(MPa)	同等C量のJIS規格鋼の変形抵抗との比	割れ限界据込み率(%)	加熱温度(℃)	表面硬度(Hv)	硬化深さt(mm)	t/r	オーステナイト粒度番号
本発明例	1	A	1250	692	0.86	≥85	950	630	6.9	0.34	5.2
	2	B	1250	712	0.88	≥85	950	621	7.4	0.37	6.7
	3	C	1250	710	0.86	≥85	950	758	6.2	0.31	5.2
	4	D	1250	711	0.88	≥85	1150	639	6.8	0.34	5.7
	5	E	1250	713	0.88	≥85	1150	630	6.3	0.32	7.0
	6	F	1250	692	0.84	≥85	1150	758	6.7	0.33	5.6
	7	G	1250	727	0.89	≥85	1150	707	6.4	0.32	5.1
	8	H	1250	699	0.86	≥85	1150	691	6.5	0.32	7.5
	9	I	1250	733	0.89	≥85	1150	737	6.6	0.33	6.2
	10	J	1250	725	0.89	≥85	1150	657	6.4	0.32	5.1
	11	K	1250	703	0.86	≥85	1150	730	6.3	0.31	6.8
	12	L	1250	690	0.83	≥85	1150	764	6.5	0.32	7.4
	13	M	1250	655	0.81	≥85	1150	630	6.3	0.31	8.2
	14	N	1250	724	0.89	≥85	1150	699	6.7	0.34	5.4

[0065]

[Table 4]

区分	試験番号	鋼	熱間鍛造における加熱温度(℃)	試験			高周波焼入れ				
				据込み抵抗(MPa)	同等C量のJIS規格鋼の変形抵抗との比	割れ限界据込み率(%)	加熱温度(℃)	表面硬度(Hv)	硬化深さt(mm)	t/r	オーステナイト粒度番号
比較例	15	D	*1100	713	0.88	**75	1150	635	6.1	0.31	**4.2
	16	E	*1100	715	0.88	**70	1150	635	6.0	0.30	**4.0
	17	*a	*1100	764	0.91	**75	1150	813	5.9	**0.29	6.0
	18	*b	*1100	751	0.93	**75	1150	839	5.3	0.35	5.4
	19	*c	*1100	815	1.01	**75	1150	839	7.3	0.37	6.7
	20	*d	1250	761	0.92	**75	1150	737	7.2	0.36	6.2
	21	*e	1250	690	0.85	**75	1150	657	5.9	0.30	**4.8
	22	*f	1250	703	0.85	**75	1150	737	6.9	0.35	5.6
	23	*g	1250	725	0.88	**75	1150	730	6.6	0.33	5.3
	24	*h	1250	759	0.92	**80	1150	744	7.8	0.39	5.5
	25	*i	1250	735	0.91	≥85	1150	630	6.6	0.33	**4.6
	26	*j	1250	740	0.91	≥85	1150	666	5.2	**0.26	**4.4
	27	*k	1250	677	0.82	≥85	1150	737	6.5	0.33	**5.1
	28	*l	1250	723	0.89	**80	650	639	4.1	**0.21	**2.8
	29	*m	1250	743	0.90	**70	950	751	4.2	**0.21	6.7
	30	*n	1250	716	0.88	**70	950	666	4.2	**0.21	5.6
	31	*o	1250	726	0.88	**70	950	722	3.8	**0.19	5.8
	32	*p	1250	806	1.00	≥85	1150	621	5.8	**0.29	**3.2
	33	*q	1250	819	1.00	**80	1150	707	5.6	**0.28	**2.8
	34	*r	1250	829	1.00	**78	1150	764	5.5	**0.27	**3.8

*印は本発明で規定する条件から外れていることを、**印は目標に未達であることを示す。

アンダーラインを付けたオーステナイト粒度番号は混粒が存在する場合の平均値であることを示す。

[0066] What used as the base material steel A-N of the example of this invention which has chemical composition within the limits of the content specified by this invention, and heated at 1250 degrees C from Table 3 at the time of hot forging (test numbers 1-14) is set to the JIS machine structural carbon steel of equivalent C content, deformation resistance with a rate [of a lump] of 60% (it is 1.0 at the average equivalent strain of each part of a test piece) is low 10% or more, the limitation which the crack as deformability generates sets, and the rate of a lump is 85% or more. And t/r is 0.3 or more, and even if it carries out induction hardening on condition that [former / of heating unit skin temperature / of 1150 degrees C /, and holding-time 10 seconds] an elevated temperature and long duration, the austenite grain size of a hardening hardening layer is a particle size regulation by five or more JIS grain-size numbers.

[0067] Even if it is the steel of the example of this invention which has chemical composition within the limits of the content specified by this invention from Table 4, when whenever [stoving temperature / at the time of hot forging] is less than a convention of 1100 degrees C and this invention (test numbers 15 and 16), a limitation sets and the rate of a lump has not reached to 85%.

[0068] Moreover, in using steel of the example of a comparison as a base material, do not fill the fall cost of deformation resistance to 10% to the JIS machine structural carbon steel of C content of a (b) EQC. (**) — t/r when carrying out induction hardening (Ha) which a limitation sets and the rate of a lump is not filled to 85% is less than 0.3 — It corresponds to any one or more ** which the hard spot after (d) induction hardening, i.e., the austenite grain size of a hardening hardening layer, is less than five JIS grain-size number, or are mixed grain sizes although austenite grain sizes are five or more JIS grain-size numbers. For this reason, cold-working nature and induction hardening nature are incompatible.

[0069]

[Effect of the Invention] Since it excels in the cold-working nature and induction hardening nature after spheroidizing, it does not coarse-grain-ize even if it carries out induction hardening on condition that [which it moreover says is heating unit skin temperature / of 1150 degrees C /, and holding-time 10 seconds] an elevated temperature and a long time, but a ready fine grain is presented, this invention steel can be used as base materials, such as machine structural steel worker components and a constant-velocity joint which are the circumference components of a guide peg of an automobile especially. This machine structural steel worker component can be manufactured comparatively easily by the approach of this invention.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is drawing showing the relation between deformation resistance and the content of C.

[Translation done.]

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(54) 【発明の名称】 高周波焼入れ性に優れた冷間加工用鋼及び機械構造用部品並びにその製造方法

(57) 【要約】

【課題】 球状化焼鈍後の冷間加工性と高周波焼入れ性に優れ、従来よりも高温且つ長時間の条件で高周波焼入れしても粗粒化せず整細粒を呈する鋼と、それを母材とする機械構造用部品及びその製造方法を提供する。

【解決手段】 ① C: 0.40~0.60%、Si: 1.0超~0.30%、Mn: 0.10~0.60%、B: 0.0005~0.005%、Nb: 0.005~0.05%、Ti: 0.005~0.05%、Al: 0.050超~0.10%を含有し、残部Feと不純物で、不純物中のP≤0.015%、S≤0.015%、Cu≤0.10、Ni≤0.10%、Cr≤0.15%、Mo≤0.10%、N≤0.005%、O≤0.005%である高周波焼入れ性に優れた冷間加工用鋼。② 母材が①の化学組成を有し、球状化炭化物とJIS粒度番号5以上の整粒の焼入れ硬化層を備える機械構造用部品。③ 1200℃以上に加熱後熱間加工し、次いで球状化焼鈍、冷間加工して所定の形状に成形し、その後高周波焼入れして製造する。

【特許請求の範囲】

【請求項1】重量％で、C：0.40～0.60％、Si：0.10％を超え0.30％以下、Mn：0.10～0.60％、B：0.0005～0.005％、Nb：0.005～0.05％、Ti：0.005～0.05％、Al：0.050％を超え0.10％以下を含有し、残部はFe及び不可避不純物からなり、不純物中のPは0.015％以下、Sは0.015％以下、Cuは0.10％以下、Niは0.10％以下、Crは0.15％以下、Moは0.10％以下、Nは0.005％以下、O（酸素）は0.005％以下である高周波焼入れ性に優れた冷間加工用鋼。

【請求項2】母材が請求項1に記載の化学組成を有し、球状化された炭化物とオーステナイト結晶粒度がJIS粒度番号5以上の整粒の焼入れ硬化層を備える機械構造用部品。

【請求項3】1200℃以上に加熱後に熱間加工され、次いで、球状化焼鈍された請求項1に記載の化学組成を有する鋼材を、冷間加工して所定の形状に成形し、その後高周波焼入れすることを特徴とする機械構造用部品の製造方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、高周波焼入れ性に優れた冷間加工用鋼並びに機械構造用部品及びその製造方法に関する。より詳しくは、冷間加工時における変形抵抗が小さく、高周波焼入れ性に優れ、しかも、例えば加熱部表面温度が1150℃で保持時間が10秒というような、従来よりも高温且つ長時間の条件で高周波焼入れしても粗粒化することのない、つまり、整細粒である冷間加工用鋼と、その鋼を母材とした機械構造用部品及びその製造方法に関する。

【0002】

【従来の技術】従来、機械構造用部品、なかでも自動車の足廻り部品である等速ジョイントなどは、熱間鍛造されたJISの機械構造用中炭素鋼鋼材（S45CやS48Cなど）を切削して所定の形状に成形加工した後に高周波焼入れし、更に、必要に応じて焼戻しを行うことによって製造されていた。

【0003】しかしながら、熱間鍛造の場合は寸法精度が劣るので、所定の形状に成形するためには重切削する必要があり、切削加工のコストが高み、更に歩留りが低くなることを避けられなかった。そこで近年、寸法精度が高く、したがって、切削量を低減することが可能な冷間鍛造が採用されるようになってきた。

【0004】上記の冷間鍛造を行う場合には、変形抵抗を下げるために被加工材に予め球状化焼鈍が施される。しかし、前記したJISの機械構造用中炭素鋼鋼材を用いた場合、球状化焼鈍処理を行っても変形抵抗が高いため、冷間鍛造時に強加工を行うと工具寿命が低下し、

又、変形能が低いので冷間鍛造された部品に割れが生ずる場合もあった。

【0005】更に近年においては、機械構造用部品の高強度化を目的に、従来に比べて高温且つ長時間の条件で高周波焼入れを行なうことが多くなってきた。しかし、このような条件で高周波焼入れすると、前記したJISの機械構造用中炭素鋼鋼材の場合には極めて粗粒化してしまう。

【0006】このような問題に対し、高周波焼入れ性を確保しつつ、冷間鍛造性を改善させる技術が特公平1-38847号公報、特公平2-47536号公報、特開平5-59486号公報、特開平9-268344号公報、特開平9-272946号公報、特開平9-287054号公報、特開平9-287055号公報や特開平2-145744号公報などで提案されている。

【0007】しかし、特公平1-38847号公報で提案された鋼は、Alの含有量が少ないため、Bの焼入れ性向上効果が得難い場合があった。

【0008】特公平2-47536号公報、特開平5-59486号公報で提案された鋼は、Alの含有量が少ないため、Bの焼入れ性向上効果が得難い場合があり、しかも、Nbを含有していないので結晶粒の粗大化を生ずる場合があった。更に、Siの含有量が低いので、熱間加工前の加熱で生じたスケールの剥離性が劣る場合があった。

【0009】特開平9-268344号公報、特開平9-272946号公報で開示された鋼は、Alの含有量が少ないため、Bの焼入れ性向上効果が得難い場合があり、しかも、Nbを含有していないので結晶粒の粗大化を生ずる場合があった。

【0010】特開平9-287054号公報で提案された鋼は、Siの含有量が高いために冷間加工性の劣化を避け難いものであった。

【0011】特開平9-287055号公報で開示された鋼は、Mnの含有量が高いために冷間加工性の劣化を避け難いものであった。

【0012】特開平2-145744号公報で開示された技術は、NbとTiが複合添加されていない。このため、この公報で提案された鋼を高周波焼入れすると、結晶粒の粗大化を生ずる場合があった。特に、機械構造用部品を高強度化することを目的に、従来に比べて高温且つ長時間の条件で高周波焼入れを行なうと、極めて粗粒化してしまう。更に、上記の公報で提案された鋼はBを必須元素として含まないので、所望の高周波焼入れ深さが得られない場合があった。しかも、Bを含まない鋼の場合には、同等の焼入れ性を有するBを含む鋼と比べて合金元素の含有量が多いため、冷間鍛造時の変形抵抗が高くなって冷間鍛造性が劣ることがあった。加えて、熱間加工や球状化焼鈍で生成したスケールが脱スケールの工程で落ちにくく、脱スケールに長時間要したりその工

程が複雑になったりすることを避け難いものであった。
【0013】

【発明が解決しようとする課題】本発明は、上記現状に鑑みなされたもので、冷間鍛造を初めとする冷間加工時における変形抵抗が小さく、高周波焼入れ性に優れ、しかも、従来よりも高温且つ長時間の条件で高周波焼入れしても粗粒化せず整細粒を呈する低コスト型の冷間加工用鋼と、その鋼を母材とした機械構造用部品及びその製造方法を提供することを目的とする。具体的には、同等のC含有量のJIS機械構造用炭素鋼に対して、冷間加工時における変形抵抗が10%以上低く、しかも、変形能としての割れが発生する限界の据え込み率が85%以上で、高周波焼入れした時にビッカース硬度(Hv)で400となる硬化深さをt、高周波焼入れ部の平均直径をrとしてt/rが0.3以上であり、加熱部表面温度が1150℃で保持時間が10秒というような条件で高周波焼入れしても、高周波焼入れ後の硬化部、つまり、後述する焼入れ硬化層のオーステナイト結晶粒度がJIS粒度番号5以上で、且つ、整粒であることを目標とする。なお、高周波焼入れ後の硬化部である「焼入れ硬化層」はHvで400以上となる部分のことを指す。「整粒」とは、粒度番号で3以上差のない粒からなることをいう。

【0014】

【課題を解決するための手段】本発明は、下記(1)に示す高周波焼入れ性に優れた冷間加工用鋼、並びに、(2)に示す機械構造用部品及び(3)に示す機械構造用部品の製造方法を要旨とする。

【0015】(1)重量%で、C:0.40~0.60%、Si:0.10%を超え0.30%以下、Mn:0.10~0.60%、B:0.0005~0.005%、Nb:0.005~0.05%、Ti:0.005~0.05%、Al:0.050%を超え0.10%以下を含有し、残部はFe及び不可避不純物からなり、不純物中のPは0.015%以下、Sは0.015%以下、Cuは0.10%以下、Niは0.10%以下、Crは0.15%以下、Moは0.10%以下、Nは0.005%以下、Oは0.005%以下である高周波焼入れ性に優れた冷間加工用鋼。

【0016】(2)母材が上記(1)に記載の化学組成を有し、球状化された炭化物とオーステナイト結晶粒度がJIS粒度番号5以上の整粒の焼入れ硬化層を備える機械構造用部品。

【0017】(3)1200℃以上に加熱後に熱間加工され、次いで、球状化焼鈍された上記(1)に記載の化学組成を有する鋼材を、冷間加工して所定の形状に成形し、その後高周波焼入れすることを特徴とする機械構造用部品の製造方法。

【0018】なお、上記(2)でいう「焼入れ硬化層」とは、既に述べたように焼入れでHv400以上とな

た部分のことを指し、「整粒」とは、粒度番号で3以上差のない粒からなることをいう。

【0019】本発明者らは、球状化焼鈍後に冷間鍛造などの冷間加工によって塑性加工し、次いで従来よりも高温長時間での高周波焼入れによって製造される機械構造用部品の母材となる鋼の化学組成について調査・検討を行った。その結果、下記の知見を得た。

【0020】①NbとTiを複合添加した鋼が凝固する際に析出するニオブチタン炭窒化物〔NbTi(CN)〕は粗大であるため、高周波焼入れ時のオーステナイト粒の粗大化防止には効果がない。しかし、前記の〔NbTi(CN)〕を微細化すると、所謂「ピン止め作用」が発揮されるので、オーステナイト粒の粗大化を防止することができる。

【0021】②〔NbTi(CN)〕を微細化するには、熱間加工の際の加熱温度を高くして一旦素地に固溶させ、次の加工・冷却時に再析出させれば良い。

【0022】③前記の微細な〔NbTi(CN)〕によるオーステナイト粒の粗大化防止は、特に鋼のMn含有量が低い場合に大きく発揮され、加熱部表面温度が1150℃で保持時間が10秒というような、従来よりも高温且つ長時間の条件で高周波焼入れしても粗粒化せず整細粒となる。

【0023】④Mn含有量を低く抑えらるとともに適正量のSi、Nb、Ti、Al及びBを含有させた鋼の場合、〔NbTi(CN)〕が微細であっても通常の球状化焼鈍で十分に軟化する。したがって、同等のC含有量のJIS機械構造用炭素鋼に比べて冷間加工時における変形抵抗は低く、しかも、変形能は充分大きい。

【0024】⑤Mn、Nb、Ti、Al及びBの含有量を調整し、不純物元素としてのNの含有量を低く調整した鋼は、良好な高周波焼入れ性を有する。

【0025】⑥C、Mn、Nb、Ti、Al及びBの含有量を調整し、不純物元素としてのNの含有量を低く調整した鋼は、加熱部表面温度が1150℃で保持時間が10秒というような、従来よりも高温且つ長時間の条件で高周波焼入れしても、前記したt/rが0.3以上を容易に満たすことができる。

【0026】本発明は、上記の知見に基づいて完成されたものである。

【0027】

【発明の実施の形態】以下、本発明の各要件について詳しく説明する。なお、化学成分の含有量の「%」は「重量%」を意味する。

【0028】(A)母材鋼の化学組成

C:0.40~0.60%

Cは、高周波焼入れ性に影響を及ぼす元素で、焼入れ硬化層の硬さ及び深さを確保して機械構造用部品に所望の機械的性質を付与するのに有効な元素である。しかし、その含有量が0.40%未満では添加効果に乏しい。一

方、0.60%を超えて含有させると、球状化焼鈍しても十分に軟化せずに冷間加工性が劣化したり、韌性の劣化や焼割れの発生を招くことがある。したがって、Cの含有量を0.40~0.60%とした。

【0029】Si:0.10%を超え0.30%以下
Siは、鋼の脱酸の安定化及び強度を高める効果がある。更に、Siを添加した鋼は、熱間加工のための加熱中に低融点酸化物であるファイアライト(Fe_2SiO_4)を生成するので、その融点(1173℃)以上に加熱すれば、脱スケール性が極めて良好になる。しかし、その含有量が0.10%以下では添加効果に乏しい。一方、0.30%を超えて含有量させると、冷間加工時の変形抵抗が大きくなって冷間加工性の低下を招く。したがって、Siの含有量を0.10%を超え0.30%以下とした。なお、好ましくはSiを0.15%を超えて含有させるのが良い。

【0030】Mn:0.10~0.60%

Mnは、鋼中のSを固定して熱間加工性を高めるとともに強度を確保するために有効な元素で、0.10%以上含有させることが必要である。一方、Mnの含有量が0.60%を超えると、変形抵抗が大きくなって冷間加工性の劣化をきたす。したがって、Mnの含有量を0.10~0.60%とした。なお、Mn含有量は0.10~0.40%とすることが好ましい。

【0031】B:0.0005~0.005%

Bは、冷間加工性を阻害することなく良好な高周波焼入れ性を確保するのに有効な元素である。しかし、その含有量が0.0005%未満では添加効果に乏しい。一方、0.005%を超えて含有させるとその効果が飽和するばかりか、粒界脆化を招く場合がある。したがって、Bの含有量を0.0005~0.005%とした。

【0032】Nb:0.005~0.05%

Nbは、Tiと結合して[NbTi(CN)]を形成するが、この[NbTi(CN)]を微細に析出させると、従来よりも高温且つ長時間の条件で高周波焼入れした場合でも粗粒化を防止することができる。しかし、その含有量が0.005%未満では所望の効果が得られない。一方、0.05%を超えると、変形抵抗を増加させることが避けられず、又、粗大な未固溶炭窒化物が残留して冷間加工性の劣化を招くことがある。したがって、Nbの含有量を0.005~0.05%とした。なお、Nb含有量の上限は0.03%とすることが好ましく、0.02%とすれば一層好ましい。

【0033】Ti:0.005~0.05%

Tiは、Nbと結合して[NbTi(CN)]を形成するが、この[NbTi(CN)]を微細に析出させると、従来よりも高温且つ長時間の条件で高周波焼入れした場合でも粗粒化を防止することができる。しかし、その含有量が0.005%未満では添加効果に乏しい。一方、0.05%を超えると、変形抵抗を増加させること

が避けられず、又、粗大な未固溶炭窒化物が残留して冷間加工性の劣化を招くことがある。したがって、Tiの含有量を0.005~0.05%とした。なお、Ti含有量の上限は0.03%とすることが好ましく、0.015%とすれば一層好ましい。

【0034】Al:0.050%を超え0.10%以下
Alは、脱酸作用を有する。更に、窒化物を生成して鋼中のNを固定するので、冷間加工時の加工硬化を抑制する作用がある。又、鋼中Nの固定によってBの高周波焼入れ性向上効果を確保するのに有効である。しかし、その含有量が0.050%以下では添加効果に乏しい。一方、0.10%を超えて含有させると、冷間加工時に鋼の変形能が低下する。したがって、Alの含有量を0.050%を超えて0.10%以下とした。

【0035】本発明においては、不純物元素としてのP、S、Cu、Ni、Cr、Mo、N及びOを下記のとおり制限する。

【0036】P:0.015%以下

Pは、冷間加工時の変形能を低下させてしまう。特に、Pの含有量が0.015%を超えると、冷間加工時の変形能の低下が著しくなる。したがって、不純物元素としてのPの含有量を0.015%以下とした。

【0037】S:0.015%以下

Sも冷間加工時の変形能を低下させてしまう。特に、Sの含有量が0.015%を超えると、冷間加工時の変形能の低下が著しくなる。したがって、不純物元素としてのSの含有量を0.015%以下とした。

【0038】Cu:0.10%以下

Cuは変形抵抗を高めて冷間加工性を劣化させてしまう。特に、Cuの含有量が0.10%を超えると、冷間加工性の劣化が著しくなる。したがって、不純物元素としてのCuの含有量を0.10%以下とした。なお、Cu含有量は0.05%以下に規制することが好ましい。

【0039】Ni:0.10%以下

Niは変形抵抗を高めて冷間加工性を劣化させてしまう。更に、球状化焼鈍後のスケール除去を困難にする。特に、Niの含有量が0.10%を超えると、冷間加工性の低下とスケール除去性の低下が著しくなる。したがって、不純物元素としてのNi含有量を0.10%以下とした。なお、Ni含有量は0.05%以下に規制することが好ましい。

【0040】Cr:0.15%以下

Crも変形抵抗を高めて冷間加工性を劣化させてしまう。更に、球状化焼鈍後のスケール除去を困難にする。特に、Crの含有量が0.15%を超えると、冷間加工性の低下とスケール除去性の低下が著しくなる。したがって、不純物元素としてのCr含有量を0.15%以下とした。なお、Cr含有量は0.10%以下に規制することが好ましい。

【0041】Mo:0.10%以下

Moは変形抵抗を高めて冷間加工性を劣化させてしまう。更に、球状化焼鈍後のスケール除去を困難にしてしまう。特に、Moの含有量が0.10%を超えると、冷間加工性の低下とスケール除去性の低下が著しくなる。したがって、不純物元素としてのMo含有量を0.10%以下とした。なお、Mo含有量は0.05%以下に規制することが好ましい。

【0042】N：0.005%以下

Nは、変形抵抗を高めて冷間加工性を劣化させてしまう。更に、容易にBと結びついてBNを形成するので、Bの高周波焼入れ性向上効果が確保できなくなる。特に、Nの含有量が0.005%を超えると、冷間加工性の低下が著しくなるとともにBの高周波焼入れ性向上効果が得難くなる。したがって、不純物元素としてのN含有量を0.005%以下とした。なお、N含有量は0.004%以下に規制することが好ましく、0.003%以下とすれば一層好ましい。

【0043】O（酸素）：0.005%以下

Oは、酸化物を形成して冷間加工時の変形能を低下させてしまう。特に、Oの含有量が0.005%を超えると、冷間加工時の変形能の低下が著しくなる。したがって、不純物元素としてのOの含有量を0.005%以下とした。

【0044】(B) 熱間加工

NbとTiを複合添加した上記(A)に記載の化学組成を有する鋼は、その凝固組織中に粗大な〔NbTi(CN)〕が存在するものである。この粗大な〔NbTi(CN)〕は、後の冷間加工における加工割れの起点となり、又、高周波焼入れ時のオーステナイト粒の粗大化防止にも効果を有さない。

【0045】しかしながら、熱間圧延を初めとする熱間*

$$\varepsilon = \{(\varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2) \times 2/3\}^{1/2} \cdots (a)$$

ここで、(a)式における ε_1 、 ε_2 、 ε_3 は主方向の対数歪である。

【0050】(E) 高周波焼入れ

前記(A)に記載の化学組成を有し、熱間加工後に球状化焼鈍され、その後で冷間加工されて所定の形状に成形された鋼材は、高周波焼入れされて、あるいは、必要に応じて高周波焼入れ後に焼戻しが施されて、所望の機械的性質を有する機械構造用部品に仕上げられる。

【0051】機械構造用部品の焼入れ硬化層におけるオーステナイト結晶粒度がJIS粒度番号で5を下回ったり、整粒でない、つまり混粒である場合には、熱処理歪が生ずることに加えて、靱性が低下し、硬さ（強度）のばらつきが生じ、特に、機械構造用部品の強度が高い場合の靱性の低下は著しいものである。したがって、機械構造用部品の焼入れ硬化層を、JIS粒度番号5以上のオーステナイト結晶粒度の整粒であるように規定した。なお、JIS粒度番号は6以上であることが好ましい。オーステナイト結晶粒は小さければ小さいほど、つまり

*加工の際の加熱温度を1200℃以上の高い温度とすれば、〔NbTi(CN)〕は一旦素地に固溶し、次の加工・冷却時に微細に再析出するので、所謂「ピン止め作用」が発揮できるので、オーステナイト粒の粗大化防止が可能となる。したがって、熱間加工の加熱温度を1200℃以上とした。なお、この加熱温度の上限は特に規定する必要はないが、加熱のためのエネルギーコストを抑え、更に、スケールロスを抑えて歩留りを高めるために、1350℃とすることが好ましい。

10 【0046】(C) 球状化焼鈍

前記(A)に記載の化学組成を有する鋼は、上記(B)に記載の条件で加熱された後熱間で加工され、更に、冷間加工時の変形抵抗を下げるために球状化焼鈍を施される。この球状化焼鈍は特に規定されるものではなく、通常の方法で行えば良い。

【0047】(D) 冷間加工

熱間加工後に球状化焼鈍された前記(A)に記載の化学組成を有する鋼材は、冷間鍛造などの冷間加工を施されて所定の形状の機械構造用部品に成形される。この冷間加工の方法は特に規定されるものではなく、通常の方法で行えば良い。

【0048】なお、冷間加工で所定の形状に成形された機械構造用部品の高周波焼入れ後の硬化部（焼入れ硬化層）が、安定して後述するJIS粒度番号5以上のオーステナイト結晶粒度の整粒組織を確保できるようにするために、冷間加工は被加工部品において最も大きな加工が加わる部分での加工量が下記(a)式で表される相当歪で2.5以下となるように行うのが良く、相当歪で2.0以下となるように行えば一層好ましい。

30 【0049】

JIS粒度番号は大きければ大きいほど靱性は向上するので、JIS粒度番号には上限を設けなくて良い。

【0052】前記(A)に記載の化学組成を有する本発明に係る鋼は、通常の条件、つまり加熱部表面温度が950℃程度で保持時間が数秒程度である条件での高周波焼入れに対しては、結晶粒が粗大化することではなく、オーステナイト結晶粒度がJIS粒度番号5以上の整細粒が得られる。更に、加熱部表面温度が1150℃で保持時間が10秒というような、従来よりも高温且つ長時間の条件で高周波焼入れしてもオーステナイト結晶粒度がJIS粒度番号5以上の整細粒が得られるように調整されたものである。このため、高周波焼入れの方法は特に規定されるものではない。

【0053】なお、冷間加工後に高周波焼入れした鋼材の振り強度は、高周波焼入れ深さとしてのHvで400以上となる硬化深さに依存し、t/rが0.3未満では振り強度が小さくなる。したがって、高周波焼入れされる部品が大型である場合、つまりrが大きい場合には、

通常の条件で高周波焼入れすると t/r で0.3以上が得られないことがある。このような場合には、 t/r で0.3以上を確保するために、例えば既に述べたような、加熱部表面温度が1150℃で保持時間が10秒というような、従来よりも高温且つ長時間の条件で高周波焼入れすることが必要になる。前記(A)に記載の化学組成を有する本発明に係る鋼は、そうした場合であっても結晶粒が粗大化することはないのである。

【0054】以下、実施例により本発明を説明する。

【0055】

*【実施例】表1、表2に示す化学組成を有する鋼を通常の方法によって試験炉を用いて溶製した。表1における鋼A～Nは化学組成が本発明で規定する含有量の範囲内にある本発明例の鋼、表1における鋼a～rは成分のいずれかが本発明で規定する含有量の範囲から外れた比較例の鋼である。比較例の鋼のうち鋼p、鋼q及び鋼rはそれぞれJIS規格のS40C、S50C及びS58Cに相当する鋼である。

【0056】

*10 【表1】

表 1

区 分	鋼	化 学 組 成 (重量%)								残部：F eおよび不純物						
		C	Si	Mn	P	S	Cu	Ni	Cr	Mo	B	Nb	Ti	Al	N	O
本 発 明 例	A	0.41	0.23	0.16	0.011	0.012	0.01	0.02	0.09	0.02	0.0020	0.017	0.015	0.068	0.0038	0.0018
	B	0.40	0.26	0.28	0.009	0.009	0.01	0.02	0.15	0.01	0.0021	0.025	0.032	0.071	0.0045	0.0013
	C	0.57	0.11	0.32	0.015	0.011	0.01	0.01	0.12	0.01	0.0015	0.015	0.014	0.067	0.0039	0.0024
	D	0.42	0.12	0.54	0.011	0.012	0.02	0.02	0.07	0.01	0.0015	0.019	0.018	0.071	0.0036	0.0024
	E	0.41	0.22	0.38	0.013	0.012	0.01	0.03	0.08	0.01	0.0015	0.021	0.036	0.027	0.0040	0.0025
	F	0.57	0.08	0.24	0.010	0.008	0.03	0.02	0.12	0.01	0.0021	0.019	0.017	0.071	0.0038	0.0022
	G	0.50	0.35	0.22	0.008	0.009	0.01	0.01	0.07	0.01	0.0015	0.007	0.018	0.077	0.0047	0.0021
	H	0.48	0.05	0.31	0.011	0.013	0.01	0.01	0.15	0.03	0.0015	0.028	0.042	0.059	0.0046	0.0017
	I	0.54	0.30	0.46	0.012	0.012	0.01	0.04	0.12	0.02	0.0015	0.025	0.017	0.059	0.0041	0.0012
	J	0.44	0.35	0.25	0.010	0.011	0.01	0.01	0.07	0.02	0.0013	0.014	0.016	0.067	0.0035	0.0016
	K	0.53	0.24	0.21	0.008	0.010	0.01	0.02	0.08	0.02	0.0017	0.017	0.039	0.045	0.0047	0.0015
	L	0.58	0.13	0.20	0.011	0.010	0.01	0.01	0.07	0.01	0.0015	0.042	0.022	0.077	0.0036	0.0025
	M	0.41	0.06	0.10	0.013	0.011	0.01	0.03	0.08	0.02	0.0015	0.026	0.046	0.061	0.0035	0.0015
	N	0.49	0.33	0.38	0.010	0.012	0.01	0.05	0.11	0.05	0.0015	0.017	0.017	0.065	0.0034	0.0014

【0057】

※ ※ 【表2】

表 2

区 分	鋼	化 学 組 成 (重量%)								残部：F e および不純物							
		C	Si	Mn	P	S	Cu	Ni	Cr	Mo	B	Nb	Ti	Al	N	O	
比 較 例	a	*0.67	0.34	0.32	0.012	0.012	0.01	0.01	0.08	0.01	0.0012	0.024	0.025	0.051	0.0031	0.0017	
	b	0.42	*0.52	0.29	0.011	0.011	0.01	0.03	0.09	0.02	0.0014	0.022	0.026	0.070	0.0022	0.0014	
	c	0.42	0.36	*0.81	0.011	0.009	0.01	0.01	0.11	0.03	0.0017	0.020	0.035	0.044	0.0033	0.0015	
	d	0.54	0.37	0.45	*0.022	0.010	0.01	0.02	0.14	0.01	0.0018	0.017	0.041	0.078	0.0038	0.0032	
	e	0.44	0.21	0.18	0.012	*0.024	0.01	0.01	0.05	0.01	0.0011	0.025	0.017	0.060	0.0029	0.0027	
	f	0.54	0.23	0.22	0.011	0.009	*0.14	0.10	0.06	0.01	0.0022	0.015	0.035	0.085	0.0044	0.0023	
	g	0.53	0.21	0.34	0.011	0.010	0.01	*0.20	0.05	0.02	0.0020	0.009	0.038	0.057	0.0037	0.0015	
	h	0.55	0.24	0.56	0.010	0.013	0.01	0.02	*0.28	0.01	0.0018	0.018	0.028	0.088	0.0043	0.0014	
	i	0.41	0.26	0.21	0.011	0.011	0.01	0.01	0.09	*0.15	0.0014	0.024	0.006	0.065	0.0032	0.0035	
	j	0.45	0.08	0.55	0.013	0.014	0.01	0.03	0.14	0.02	*	0.023	0.017	0.032	0.0045	0.0015	
	k	0.54	0.05	0.17	0.010	0.012	0.02	0.04	0.12	0.02	0.0019	*0.001	0.037	0.058	0.0026	0.0017	
	l	0.42	0.09	0.59	0.009	0.011	0.01	0.02	0.09	0.01	0.0022	0.022	*0.001	0.054	0.0038	0.0019	
	m	0.58	0.29	0.54	0.010	0.010	0.01	0.02	0.12	0.02	0.0015	0.020	0.040	*0.120	0.0047	0.0032	
	n	0.45	0.06	0.55	0.012	0.012	0.01	0.02	0.09	0.02	0.0023	0.017	0.032	0.089	*0.0075	0.0032	
	o	0.52	0.34	0.17	0.011	0.010	0.01	0.02	0.12	0.01	0.0019	0.019	0.028	0.065	0.0037	*0.0062	
	p	0.40	0.31	*0.76	*0.022	*0.018	0.01	0.02	0.15	0.01	*	-	*0.001	*0.001	0.052	*0.0053	*0.0063
	q	0.50	0.28	*0.80	*0.020	*0.020	0.01	0.02	0.15	0.01	*	-	*0.001	*0.001	0.056	*0.0063	*0.0056
	r	0.58	0.35	*0.74	*0.017	*0.016	0.01	0.02	0.13	0.01	*	-	*0.001	*0.001	0.069	*0.0061	0.0042

*印は本号明で規定する条件から外れていることを示す。

*印は本発明で規定する条件から外れていることを示す。

【0058】次いで、これらの鋼を通常の方法によって鋼片にした後、1100℃あるいは1250℃に加熱して熱間鍛造し、直径65mmの丸棒とした。その後、C含有量に応じて通常の方法で球状化焼鈍を行った。

【0059】上記のようにして得られた直径が65mmの丸棒のR/2部(Rは丸棒の半径)から、直径が15mmで長さが22.5mmの冷間加工用試験片を切り出し、500t高速プレス機による通常の方法で冷間(室温)拘束型据え込み試験を行い、割れが発生する境界の据え込み率を測定した。なお、据え込み率が85%まで、各条件ごとに5回の据え込み試験を行い、5個の試験片のうち3個以上に割れが発生する最小の加工率(据え込み率)を限界据え込み率として評価した。据え込み率85%で3個以上に割れを生じないものは、そこで試験を終了した。

【0060】更に、すべての鋼の限界据え込み率以下である60%の据え込み率(最も大きな加工が加わる試験片中心部における相当歪は1.5)の場合の変形抵抗を測定した。なお、図1に示すように、変形抵抗をCの含有量で整理し、JIS規格のS40C、S50C及びS58Cに相当する鋼p、鋼q及び鋼rの変形抵抗から求めた直線をJIS機械構造用鋼の変形抵抗とし、鋼A～Nの本発明例の鋼及び鋼a～oの比較例の鋼の変形抵抗と比較した。

【0061】又、上記の直径65mmの丸棒から、直径*

*が63mmで長さが50mmの試験片を切り出し、通常の方法によって冷間で直径が40mmまで前方押し出し加工(減面率60%(最も大きな加工が加わる試験片側表面部、つまり、試験片最外層の相当歪で1.3))を行った。この直径40mmに冷間で押し出し加工したもののから長さ50mmの試験片を採取し、これに高周波焼入れを行った。高周波加熱は、平均加熱速度を200℃/秒として、次の2条件で行った。すなわち、周波数20kHz、加熱部表面温度950℃、保持時間2秒の一般的な高周波加熱条件、及び、硬化深さを大きくして高強度化するための周波数20kHz、加熱部表面温度1150℃、保持時間10秒の高温・長時間での高周波加熱条件である。なお、冷却媒体には水を用いた。

【0062】高周波焼入れを行った後、通常の方法によって表面硬度とHvで400となる硬化深さ(つまり、焼入れ硬化層の深さ)tを測定した。次いで、電気炉を用いて150℃で30分の焼戻しを行い、通常の方法によって高周波焼入れ後の硬化部、つまり焼入れ硬化層のオーステナイト結晶粒度を測定した。

【0063】表3及び表4に上記の試験結果をまとめて示す。なお、本実施例におけるrは直径40mmの試験片の半径、つまり20mmである。

【0064】

【表3】

表 3

区分	試験番号	鋼	熱間鍛造における加熱温度(℃)	据 込 み 試 験			高 周 波 焼 入 れ				
				変形抵抗(MPa)	同等C量のJIS規格鋼の変形抵抗との比	割れ限界据え込み率(%)	加熱温度(℃)	表面硬度(Hv)	硬化深さt(mm)	t/r	オーステナイト粒度番号
本発明例	1	A	1250	692	0.86	≥85	950	630	6.9	0.34	5.2
	2	B	1250	712	0.88	≥85	950	621	7.4	0.37	6.7
	3	C	1250	710	0.86	≥85	950	758	6.2	0.31	5.2
	4	D	1250	711	0.88	≥85	1150	639	6.8	0.34	5.7
	5	E	1250	713	0.88	≥85	1150	630	6.3	0.32	7.0
	6	F	1250	692	0.84	≥85	1150	758	6.7	0.33	5.6
	7	G	1250	727	0.89	≥85	1150	707	6.4	0.32	5.1
	8	H	1250	699	0.86	≥85	1150	691	6.5	0.32	7.5
	9	I	1250	733	0.89	≥85	1150	737	6.6	0.33	6.2
	10	J	1250	725	0.89	≥85	1150	657	6.4	0.32	5.1
	11	K	1250	703	0.86	≥85	1150	730	6.3	0.31	6.8
	12	L	1250	690	0.83	≥85	1150	764	6.5	0.32	7.4
	13	M	1250	655	0.81	≥85	1150	630	6.3	0.31	8.2
	14	N	1250	724	0.89	≥85	1150	699	6.7	0.34	5.4

【0065】

【表4】

表 4

区分	試験番号	鋼	熱間鍛造における加熱温度(℃)	据え込み試験			高周波焼入れ				
				変形抵抗(MPa)	同等C量のJIS規格鋼の変形抵抗との比	割れ限界据え込み率(%)	加熱温度(℃)	表面硬度(Hv)	硬化深さt(mm)	t/r	オーステナイト粒度番号
比較例	15	D	* 1100	713	0.88	** 75	1150	635	6.1	0.31	**4.2
	16	E	* 1100	715	0.88	** 70	1150	635	6.0	0.30	**4.0
	17	*a	* 1100	764	0.91	** 75	1150	813	5.9	**0.29	6.0
	18	*b	* 1100	751	0.93	** 75	1150	639	5.3	0.35	5.4
	19	*c	* 1100	815	1.01	** 75	1150	639	7.3	0.37	6.7
	20	*d	1250	761	0.92	** 75	1150	737	7.2	0.38	6.2
	21	*e	1250	690	0.85	** 75	1150	857	5.9	0.30	**4.8
	22	*f	1250	703	0.85	** 75	1150	737	8.9	0.35	5.6
	23	*g	1250	725	0.88	** 75	1150	730	6.8	0.33	5.3
	24	*h	1250	759	0.92	** 80	1150	744	7.8	0.39	5.5
	25	*i	1250	735	0.91	≥ 85	1150	630	6.6	0.33	**4.6
	26	*j	1250	740	0.91	≥ 85	1150	666	5.2	**0.26	**4.4
	27	*k	1250	677	0.82	≥ 85	1150	737	6.5	0.33	**5.1
	28	*l	1250	723	0.89	** 80	950	639	4.1	**0.21	**2.8
	29	*m	1250	743	0.90	** 70	950	751	4.2	**0.21	6.7
	30	*n	1250	718	0.88	** 70	950	666	4.2	**0.21	5.6
	31	*o	1250	726	0.88	** 70	950	722	3.8	**0.19	5.8
	32	*p	1250	806	1.00	≥ 85	1150	621	5.8	**0.29	**3.2
	33	*q	1250	819	1.00	** 80	1150	707	5.6	**0.28	**2.8
	34	*r	1250	829	1.00	** 78	1150	764	5.5	**0.27	**3.8

*印は本発明で規定する条件から外れていることを、**印は目標に未達であることを示す。

アンダーラインを付けたオーステナイト粒度番号は混粒が存在する場合の平均値であることを示す。

【0066】表3から、化学組成が本発明で規定する含有量の範囲内にある本発明例の鋼A～Nを母材とし、熱間鍛造時に1250℃で加熱を行ったもの(試験番号1～14)は、同等のC含有量のJIS機械構造用炭素鋼に対して据え込み率60%(試験片各部の平均相当歪で1.0)での変形抵抗が10%以上低く、変形能としての割れが発生する限界の据え込み率は85%以上である。しかも、t/rが0.3以上であり、加熱部表面温度1150℃、保持時間10秒という従来よりも高温且つ長時間の条件で高周波焼入れしても、焼入れ硬化層のオーステナイト結晶粒度はJIS粒度番号5以上で整粒である。

【0067】表4から、化学組成が本発明で規定する含有量の範囲内にある本発明例の鋼であっても、熱間鍛造時の加熱温度が1100℃と本発明の規定を下回る場合(試験番号15、16)には、限界の据え込み率が85%に達していない。

【0068】又、比較例の鋼を母材とする場合には、(イ)同等のC含有量のJIS機械構造用炭素鋼に対して変形抵抗の低下代が10%に満たない、(ロ)限界の

据え込み率が85%に満たない、(ハ)高周波焼入れした時のt/rが0.3未満である、(ニ)高周波焼入れ後の硬化部、つまり焼入れ硬化層のオーステナイト結晶粒度がJIS粒度番号5未満であるか、オーステナイト結晶粒度はJIS粒度番号5以上であるものの混粒である、のいずれか1つ以上に該当する。このため、冷間加工性と高周波焼入れ性とが両立しない。

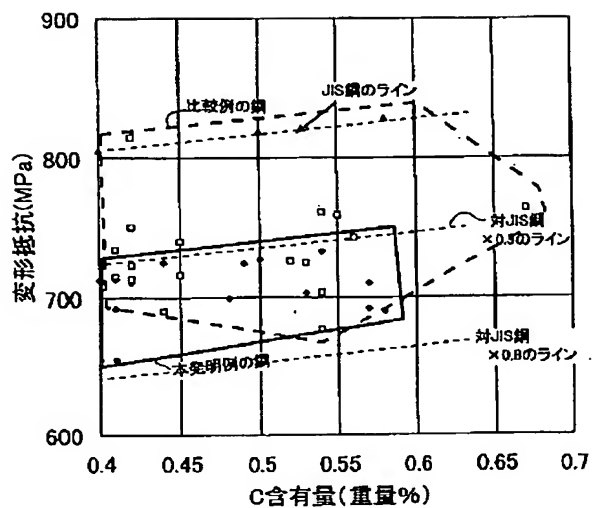
【0069】

【発明の効果】本発明鋼は、球状化焼鈍後の冷間加工性と高周波焼入れ性に優れ、しかも加熱部表面温度1150℃、保持時間10秒というような高温・長時間の条件で高周波焼入れしても粗粒化せず整細粒を呈するので、機械構造用部品、なかでも自動車の足廻り部品である等速ジョイントなどの母材として利用することができる。この機械構造用部品は、本発明の方法によって比較的容易に製造することができる。

【図面の簡単な説明】

【図1】変形抵抗とCの含有量との関係を示す図である。

【図1】



フロントページの続き

Fターム(参考) 4K032 AA01 AA02 AA05 AA06 AA16
 AA22 AA31 AA35 BA02 CA03
 CF00
 4K042 AA22 BA05 BA14 CA02 CA05
 CA06 CA08 CA09 CA10 CA12
 DA01 DB01